Behavior of the German Cockroach, *Blattella germanica* (L.), in Response to Surface Textures[1]

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Abstract: Experiments were conducted to determine the influence of various horizontally orientated textured surfaces on the congregating behavior of the German cockroach, *Blattella germanica* (L.). Various grades of sandpaper and sheets of sandpaper with the sand removed were used as testing surfaces. When these sheets were stacked in battery jars with spaces between them for the cockroaches to congregate, and the jars contained no food or water, the cockroaches showed a preference for the smoother surfaces. However, when food and water were supplied to these same jars, strong preferences for a surface of any one texture no longer existed. When, instead of being stacked, the textured surfaces were placed on the same horizontal level and the food and water were added, this species showed a strong tendency to congregate on the smoother surfaces.

The research reported in this paper deals with the behavioral responses of the German cockroach *Blattella germanica* (L.) to the texture of the surfaces upon which they congregate. In our studies, we are attempting to investigate the influence or single environmental variables on the behavior of this species, with our long-term goal being the collating of all related research. From this, it is hoped to gain a better understanding of what environmental factors influence the distribution and behavior of this species, and the interaction of these factors in the "total" environment.

In our experimental designs, we have attempted to analyze group behavior. We have chosen this line of investigation, instead of experimenting with single cockroaches, due to the broad range of variation shown by individuals of this species.

Many authors have explored the response of the German cockroach to environmental factors. In testing attractiveness of food, Pettit (1940) found that he was unable to duplicate the results of preference tests, finding that almost any food substance seemed attractive to them at some time. He did note, however, a preference for bananas, beer, milk, and bread over fresh fruits, greens, and meats.

In response to light, members of this species are photonegative and seldom

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venture forth during daylight; they are most active in early evening, less active in late evening and early morning, and relatively inactive during the day (Wille, 1920).

Ledoux (1945), in studying the gregariousness of the German cockroaches, found them to be chemopositive to odors produced by others of this species. To confirm this work, (Berthold and Wilson, 1967) placed adult German cockroaches in containers offering a choice of resting surfaces: those impregnated with odors from prior German cockroach occupation, and new surfaces free of cockroach odor. A statistically significant majority of the cockroaches tested (82%) chose to congregate on the odorous surface.

Fletcher (1961), who studied the attractancy for cockroaches of 18 esters, found that benzyl acetate exhibited some attractancy for male German cockroaches and that octyl acetate was attractive to both sexes; he also found that the number of positive responses to these two compounds increased directly with increased concentration.

In response to moisture, Gunn and Cosway (1938) found that dessicated German cockroaches spend more time in regions of high moisture, but under normal, nondessicated conditions, spend more time in low-moisture regions. Roth and Willis (1952) further demonstrated that this hygro-selective ability is lost when the 13th antennal segments of the males and the 11th of the females are removed. Gunn (1935) also found that German cockroaches preferred a temperature around 35° C.

Ledoux (1945) observed the cockroach to be thigmopositive, resting and hiding in places that provide contact above and below. Berthold and Wilson (1967) further found that this selection of constricted spaces in which the cockroaches rest can be highly selective; approximately 85% of those tested chose to congregate in spaces 3/16 of an inch in height rather than in spaces 2, 4, 5, 6, 7, or 8/16 of an inch in height.

MATERIALS AND METHODS

Five grades of sandpaper (Behr-Manning, Mohawk Flint) were used: extra fine, fine, medium, coarse, and extra course. To produce a sixth surface texture, sheets of sandpaper were soaked in warm water to remove the sand particles and allowed to air-dry. This surface was chosen rather than a material such as glass in order to eliminate the possibility of introducing such other variables as surface odor, light reflection, or heat conduction. Squares of these six sandpapers (10-cm on a side) were then glued, textured side up, to 6-mm-thick Masonite plaques of the same size.

The cockroaches were exposed to the sandpaper surfaces as follows:

Dry-washed sand was poured into battery jars (23 cm high, 15 cm diameter) with enough sand being added to produce uniformly flat bottoms in the jars. A thin band of vaseline was applied around the inner openings of the jars to

prevent the cockroaches from escaping. A plaque with no sandpaper was then slightly embedded (3 mm) in the sand, on top of which a plaque was placed, textured side up. Three 4.5-mm spacers were then placed on top of the plaque, and on top of the spacers a window glass plate (10 cm on a side) was placed. The glass forces the cockroaches to walk on the surfaces being tested. The next sandpaper-surfaced-plaque was then placed on top of the glass plate, and the procedure—spacers, glass plate, textured surface—is repeated until each of the six surfaces was present. A plain plaque was placed on top of the last glass plate.

Since we knew (Berthold and Wilson, 1967) that some type of behavior-influencing gradient is present when the German cockroach is kept in battery jars, a Latin square design (Steel and Torrie, 1960) was employed to determine the vertical position of the six different surfaces in each of six battery jars.

In the first series of tests, 20 adult male and 20 adult female cockroaches were placed in each of the six jars for a 24-hour test period (10 hours of light, 14 hours of dark). In a replication of this test, new surfaces and clean glass plates were used.

The second series of tests followed the same procedure except that the cockroaches were given food and water.

Cockroaches on the surfaces were counted by the following method (Berthold and Wilson, 1967): Squares of aluminum (20 cm sides) were folded down the center to produce two rectangular sides (10 by 20 cm) at right angles to each other. At the end of the testing period, these folded squares were gently slipped down opposite corners of the stack of plaques and pressed together, confining the cockroaches to whatever surface they are congregating at the time. Carbon dioxide was then pumped into the jar to anesthetize the cockroaches. Next, the aluminum device was removed, the testing apparatus disassembled, and the number of cockroaches on each surface recorded. Results were analyzed by use of the F-test (Dixon and Massey, 1957).

The third series of tests which utilized a different type of testing device placed all six differently textured surfaces on the same horizontal level and with food and water. This device consists of a glass-bottomed rectangular glass enclosure 56 cm long, 25 cm wide, and 10 cm high. A thin band of vaseline was applied around its upper inside edges to prevent the cockroaches from escaping. Six such enclosures were used. The six textured surfaces were placed symetrically in each enclosure, and the overall arrangement was determined by a Latin square design.

Three 4.5-mm wood spacers were then placed on top of each textured surface to support a 10-cm-square window-glass plate. On top of the glass plates, plain Masonite plaques were placed, and on top of each plaque a piece of dry dog biscuit and a petri dish bottom containing water-soaked cotton were placed.

Table 1. German cockroach response to various horizontally orientated surface textures.

Replications	Surfaces*						
	a	b	c	d	e	f	Total
Surfaces stacked in battery jars with no food or water.							
1	89	31	11	14	20	19	184
2	101	20	21	23	34	18	217
Total	190	51	32	37	54	37	401
Surfaces stacked in battery jars with food and water.							
1	37	25	39	32	60	6	199
2	71	21	27	35	34	35	233
Total	108	46	66	67	94	51	432
Surfaces on same horizontal level with food and water.							
1	62	4	6	8	11	14	105
2	48	21	17	9	3	0	102
Total	110	25	23	17	18	14	207

* Key: a—sandless sandpaper; b—very fine sandpaper; c—fine sandpaper; d—medium sandpaper; e—coarse sandpaper; f—very coarse sandpaper.

Adult cockroaches, 20 males and 20 females, were placed in each container and left undisturbed for 24 hours (10 hours of light and 14 hours of dark).

The number of cockroaches on each surface at the end of the 24-hour period was determined by placing an aluminum divider (much like a large ice cube tray divider) in the enclosure dividing it into six cockroach-tight compartments. The cockroaches are anesthetized by carbon dioxide pumped into the enclosure; each textured-surface-complex was then disassembled and the number of cockroaches in it recorded. Results were analyzed by the chi-square (χ^2) statistic (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Results for the three series of tests are presented in Table 1.

Analysis of the results of the first series (battery jars with no food and water) yield F-test values of 7.21 for the treatment effect and 0.61 for the arrangement effect. With 1/9 degrees of freedom and interrelating in an F-test table, the texture of surfaces in this series is shown to influence where this species congregate; the margin of possible error is 2.5%. Preference for a plain paper surface is indicated. The position of the surfaces in the jars apparently has no effect (0.01% margin of error).

Analysis of the results on the second series of tests (food and water included in the jars) indicates that the presence of food and water produces a marked change in the behavior observed in the absence of these factors. F-test

analysis of these data yields values of 4.08 and 6.69 (1/9 degrees of freedom) for the effects of type of surface and position of the surfaces, respectively. Interrelation indicates that, statistically, there is only a weak chance (margin of error greater than 10%) that surface textures under these conditions influence where this species congregates. Surface position in the jars apparently does have an influence on where cockroaches congregate (margin of error 5%).

Analysis of the third series of tests (glass-enclosures with food and water) indicates a tendency for this species of cockroach to congregate on the smoother-textured surfaces. Chi-square (χ^2) analysis of the data ($\chi = 220$; 5 degrees of freedom) indicates a probability of less than 0.05% that this is a random distribution.

In nature, if the cockroach is to survive in its multi-factor environment, it has to pattern its behavior. For example, the German cockroach is said to be photonegative, which might be considered a primary response, but, if he is prevented from obtaining water for a period of time, he will go into lighted places to obtain it. Hence a "primary" response has been relegated to a "secondary" status until the physiological need for water is satisfied.

The research reported in this paper may possibly fit into this concept, that is, that behavioral responses vary in degree in accordance with the environmental conditions then existing. In nature, water (also humidity) and food, plus other factors such as temperature, light and lebido, are dominant factors influencing the behavior of this species. Gunn and Cosway (1938) observed distinct cockroach behavior patterns associated with humidity, and there is the possibility, though at the present time we have made no measurements, that the presence of water in the battery-jar-tests produces a behavior-influencing gradient. If this is so, then in the jars containing no water, it would have been negligible, and in the glass enclosures it would have been constant.

With the major behavior-influencing factors now held relatively constant, other factors previously secondary may become primary. Such is the case with surface texture, and it seems reasonable to postulate that the smoother surfaces are more "comfortable" than the rougher ones for the congregating cockroaches.

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